

# The State of Industry X in Automotive



**CENTER FOR  
AUTOMOTIVE  
RESEARCH**

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CAR would also like to thank the industry respondents who participated in this study. As with all studies, CAR's industry partners provided thoughtful participation in interviews, roundtable discussions, reviews, and commentary for this effort. Their input significantly contributed to the integrity of our research. Their participation represents significant effort, analyses, and contemplation. CAR appreciates the importance, honesty, and sincerity these individuals placed on this task and their commitment to a collaborative process. We cannot overstate their efforts.

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CAR's mission is to conduct independent research and analysis to educate, inform and advise stakeholders, policymakers, and the general public on critical issues facing the automotive industry, and the industry's impact on the U.S. economy and society.

# Executive Summary

## Introduction

With the support of a unique and powerful consortium of technology companies, the Center for Automotive Research (CAR) investigated the state of Industry X in automotive. Although the research included mostly North American participants, and thus presents a North American perspective, the participating companies are global.

Industry X acknowledges that the pace of change has become so rapid that it no longer makes sense to think of manufacturing and production as advancing in discrete stages. The digital technologies that gave rise to the concept of “Industry 4.0” have continued to improve. No organization can reasonably aspire to adopt a state-of-the-art digital enterprise architecture because “state-of-the-art” is sure to advance by some degree by the time a new enterprise architecture is deployed.

This project presents an ecosystem approach to Industry X research. Industry X is a massive, complex, and rapidly evolving sector. The CAR research team thinks it is unlikely that any entity or individual can fully comprehend the depth and breadth of Industry X. To use a well-worn phrase, *it takes a village* to implement—and research—Industry X. The CAR Industry X ecosystem team consists of **Hardware (Dell and Intel), Data Management (Cloudera), Digital Automation and Analytics (Rockwell Automation and PTC), Consulting (Accenture), and Cloud Infrastructure (Microsoft Azure)**. These companies provided financial support—but equally important, they provided the CAR research team with unmatched technical and strategic knowledge and perspective. Throughout the project, the CAR researcher’s interaction with the industry and the consortium members proved that no one participant has all the answers. A collaborative ecosystem would be a beneficial environment for all of these stakeholders.

The CAR State of Industry X in Automotive project used three main research methods: long-form interviews, industry stakeholder roundtables, and a brief, targeted technology survey of interviewees. The combined inputs enabled the research team to gather a snapshot of Industry X in the North American automotive industry and identify essential guideposts. The team conducted long-form interviews with six vehicle manufacturers and 11 automotive suppliers with operations in North America. CAR researchers also interviewed, often in iterative discussions, technology experts from the consortium member companies. The consortium member discussions allowed CAR researchers to explore interview results, test hypotheses, and seek alternative perspectives. **CAR estimates nearly 50 industry stakeholders participated in the research process.** CAR also hosted a session at the 2020 Management Briefings (CAR MBS) and conducted three webinars to highlight and explore the topic and findings.

Strategy is the overarching driver of Industry X, but the processes used to implement technology change and empower the workforce will determine the outcomes. The report follows this model, starting with strategy, then focusing on people and technology as elements of the implementation process. Respondents made it clear that while Industry X will struggle without a proactive strategy, efforts will also be doomed without an effective and responsive implantation plan.

The CAR State of Industry X in Automotive project focused on the digitalization of manufacturing processes—the conversion of materials to products. However, the related data is flowing further, faster, and in far more significant quantities than ever before. And it will continue to expand. The automotive industry is racing headlong into the world of digitalization. The respondents fully understood that there will be mistakes along the way.

## Strategy

CAR researchers did not find a consistent decision-making pattern to create and implement an Industry X strategy. There was no “cookie-cutter” model. Some respondents described a specific initiative’s decision process, but it was not unusual for the decision processes to vary across the enterprise. They also described their decision processes as fluid, as companies reorganize, reprioritize, and evolve their Industry X strategies. Industry X is extraordinarily complex and always evolving—few, if any, fully comprehend all aspects of the change. That uncertainty reverberated throughout to project’s interviews and roundtable discussions.

The project highlighted three broad approaches to Industry X strategy: Most OEMs and a few suppliers described their Industry X strategy as a *top-down* rational planning process. These companies typically adopted an “Industry 4.0” strategy soon after German industries introduced it around 2015. Some companies are implementing Industry X from the middle-out. These companies financially support initiatives from the corporate level but delegate the strategy and development to targeted plants or facilities. Finally, some companies identified a bottom-up approach, depending on specific plants and facilities, to determine how to make technology investments. The bottom-up model was often associated with a single individual—an evangelist—or a small team of like-minded individuals.

CAR research found that all of the companies which participated in this study were committed to digital transformation. Interviewees understood that Industry X adoption is a continual learning process. They considered digital transformation as a journey instead of a singular event. Many of the companies interviewed are in the early stage of their journey. It was also apparent that most companies on the pathway need guidance. And some might not know—or at least are not willing to admit—that they need guidance.

The main reasons identified to pursue digital transformation were:

- Better serving the customer
- Keeping up with competitors
- Improving the bottom line
- Obtaining value from data
- Environmental sustainability

CAR research revealed several challenges in prioritizing investments. Below are the common themes:

- Building partner ecosystems
- Broadening deployments and implementations
- Scaling and global platforms
- Maintaining focus while dealing with complex technologies
- Forming effective partnerships with the right companies
- Effectively connecting information technology (IT) and operational technology (OT)

## Process Implementation

Successful digital transformation requires more than a good strategy and adequate funding. To successfully transition to Industry X, companies must be experts at process implementation. Industry X process implementation involves two critical assets: the technology and the human resource/talent. Understanding the relationship between these two is essential for success in this space. Many respondents stated that an effective change manager onsite is critical to a successful Industry X implementation. The challenge of implanting change during production—or even during program launch is daunting. Having a person that understands the role technology and people play in the process can make it much more achievable.

Industry X is often solely perceived as a collection of “shiny” new tools and methods for collecting, analyzing, and utilizing data. But obtaining value from machines and data will ultimately depend on skilled human operators and specialists. Successful implementation of Industry X should rely on the workforce’s experience, intelligence, and passion.

## Talent Process Implementation

The interviews and roundtable discussions illustrated differences between an experienced, knowledgeable legacy workforce and the opportunity provided by the (younger) more technologically-savvy workforce of the future. The research also highlighted how Industry X is forcing traditional roles, relationships, and responsibilities within the manufacturing sector to evolve rapidly.

The roundtable discussions with industry stakeholders highlighted the tension between Information technology, operations technology functions, and the production worker—and the need to get each group to buy into the process plan.

While many C-suited executives may not sufficiently understand the complexities and vagaries of the OT-IT-production worker interaction, their leadership can (positively or negatively) affect Industry X implementation. Some of our respondents stated their digital transformation initiatives began at the C-level. A clear, thoughtful vision from the C-suite gave the OT and IT a “North Star” to follow. Without a “North Star,” it can be challenging to get everybody moving in the right direction.

## Technology Process Implementations

CAR researcher conducted long-form interviews and a brief follow-up survey with the respondents. While a small sample, the two tools provided CAR researchers with a fascinating snapshot of how a leading group of automotive stakeholders are implementing Industry X technology. The interviews and surveys explored technologies (e.g., machine learning, augmented reality, cobots) and application processes (e.g., predictive maintenance, factory energy management, supply-chain optimization).

Between the interviews and the survey’s companies described various technologies and processes being considered and implemented. They also appeared to show restraint in implementing new technologies. Many had admitted to chasing technology for technology at some point but stated they had moved past that stage. Instead, technology is now more likely to be considered with a focus on the business case. Possibly the most intriguing response was the reported a lack of current interest in 5G. While it is a small sample size, the fact that only 1 of the respondents had already implemented 5G was noteworthy.

## Conclusions

For this project, the CAR research team extensively examined how key industry stakeholders view Industry X. Based on interviews and roundtables with a diverse group of Industry X stakeholders, the State of Industry X in Automotive research identified several critical conclusions. Below are selected conclusions:

- **Industry X is Really Difficult:** Industry X implementation is complex, massive, and rapidly evolving. It quickly became apparent that few, if any, companies can navigate it alone. While the research did not identify the most effective ecosystem—and many models described during the interviews—companies are exploring how best to leverage needed knowledge and technology.
- **Most companies are (mostly) “all in”:** The interviewed companies are focused on digitizing manufacturing and production. Regardless of a range of strategies and approaches, digitization is a priority across the companies interviewed for this project.
- **No matter who leads, a flexible strategy is necessary:** Enterprise-wide implementation Industry X is most successful if driven by executive and board buy-in. However, whether Industry X is driven by a top-down, middle-out, or bottom-up process, a coherent, flexible strategy is paramount for success. That strategy should establish the foundation for the implementation of both technology and talent management.
- **There is value in the data:** Most companies are looking towards Industry X to facilitate new revenue streams that capture the value of data produced in the production or use of the manufactured goods. The general theme presented by respondents is that the data is becoming as valuable as the product. However, in most cases, that value has yet to be realized.
- **Moving from proof of concept to scale is transformative:** But that step is a journey. The process brings opportunities that were not possible before. However, the broad implementation of Industry X requires a level of system thinking that may push many companies out of their comfort zone. The CAR research team thinks it is essential to consider how companies may better adjust the reward structure to encourage a more dynamic system solution to Industry X implementation.
- **OT and IT are fusing:** Industry X’s success requires the unprecedented blending of IT and OT expertise, as well as hands-on experience. Companies should take care to achieve understanding and build a reward structure that encourages collaboration.

Automotive stakeholders are moving beyond merely chasing “shiny” new technologies to something more systematic and powerful. But, they are still early on that journey—very early. Implementing Industry X presents a *paradox of perspective*. Digital transformation requires a level of coordination, cooperation, and communication that makes many companies uncomfortable. It connects people and functions in ways they have never been before. On the surface, Industry X is a technology-driven concept. However, this report illustrates it to be about transformative change. At its core, this change is about the people: From the C-level to the information technology and operational technology implementors and the production floor workers, Industry X requires a willingness to change. And change is difficult.



# Introduction: Industry X, the Ecosystem and Research

## Industry X: An Unending Evolution

Industrial economists think of the history of manufacturing as a series of four industrial revolutions, culminating in “Industry 4.0.” The fourth industrial revolution is the digitalization and integration of manufacturing and production technologies across an enterprise. “Industry X” carries this effort into the increasingly uncertain future.

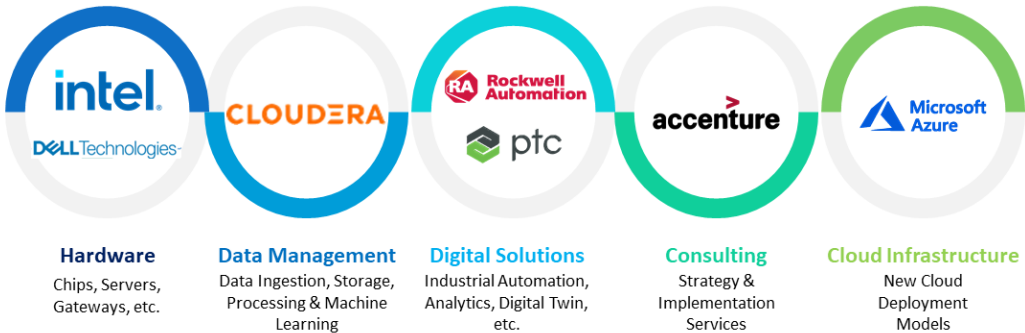
Industry X acknowledges that the pace of change has become so rapid that it no longer makes sense to think of manufacturing and production as advancing in discrete stages. The digital technologies that gave rise to the concept of “Industry 4.0” have continued to improve. No organization can reasonably aspire to adopt a state-of-the-art digital enterprise architecture because “state-of-the-art” is sure to advance by some degree by the time a new enterprise architecture is deployed.

## A Research Ecosystem

With the support of a unique and powerful consortium of technology companies, the Center for Automotive Research (CAR) investigated the state of Industry X in automotive. Although research included mostly North American participants, and thus presents a North American perspective, the participating companies are global.

This project presents an ecosystem approach to Industry X research. Industry X is a massive, complex, and rapidly evolving sector. The CAR research team thinks it is unlikely that any entity or individual can fully comprehend the depth and breadth of Industry X. To use a well-worn phrase; *it takes a village* to implement—and research—Industry X. The CAR Industry X ecosystem team consists of **Hardware (Dell and Intel)**, **Data Management (Cloudera)**, **Digital Automation and Analytics (Rockwell Automation and PTC)**, **Consulting (Accenture)**, and **Cloud Infrastructure (Microsoft Azure)**. These companies provided financial support—but equally important, they provided the CAR research team with unmatched technical and strategic knowledge and perspective. If there was any doubt early on about the need for a comprehensive ecosystem approach, the CAR researcher’s interaction with industry and the ecosystem members proved that no one participant has all the answers.

Figure 1: Industry X Project Ecosystem: Funding and Perspective



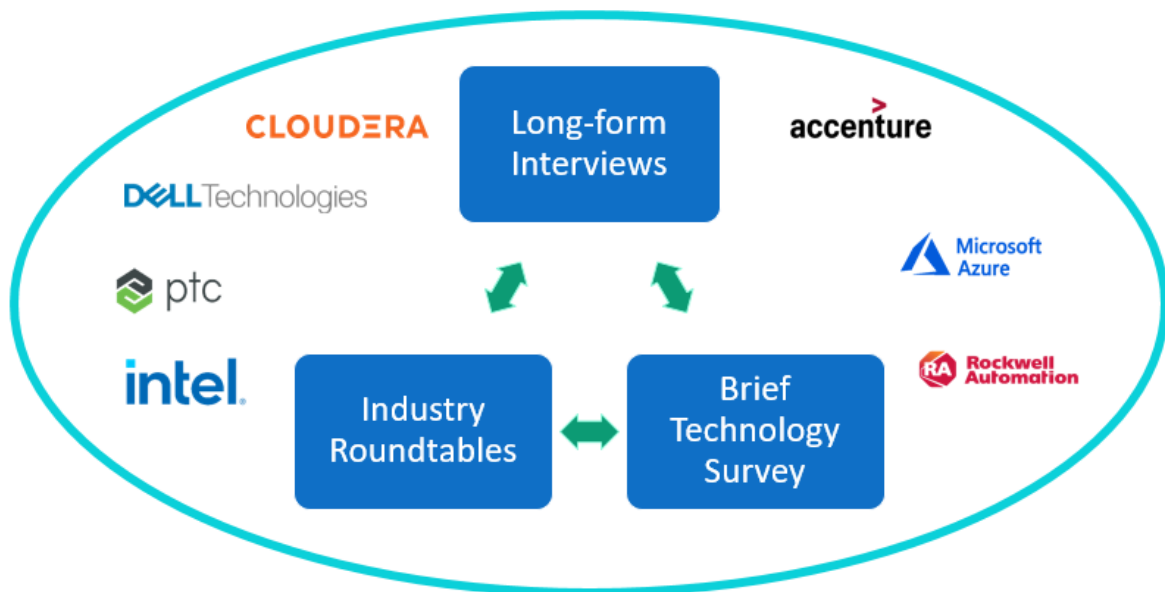
Source: CAR Research

## The Research Project

### Multiple Inputs to a Complex Question

The CAR State of Industry X in Automotive project used three main research methods: long-form interviews, industry stakeholder roundtables, and a brief, targeted technology survey of interviewees.<sup>1</sup> The combined inputs enabled the research team to gather a snapshot of Industry X in the North American automotive industry and identify essential guideposts. The team conducted long-form interviews with six vehicle manufacturers and 11 automotive suppliers with North American operations. CAR researchers also interviewed, often in iterative discussions, technology experts from the consortium member companies. The consortium member discussions allowed CAR researchers to explore interview results, test hypotheses, and seek alternative perspectives. CAR estimates nearly 50 industry stakeholders participated in the research process. CAR also hosted a session at the 2020 Management Briefings (CAR MBS) and conducted three webinars to highlight and explore research findings. Figure [2] illustrates the multiple inputs to the CAR research effort.

Figure 2: Industry X Project: Multiple Research Inputs



Source: CAR Research

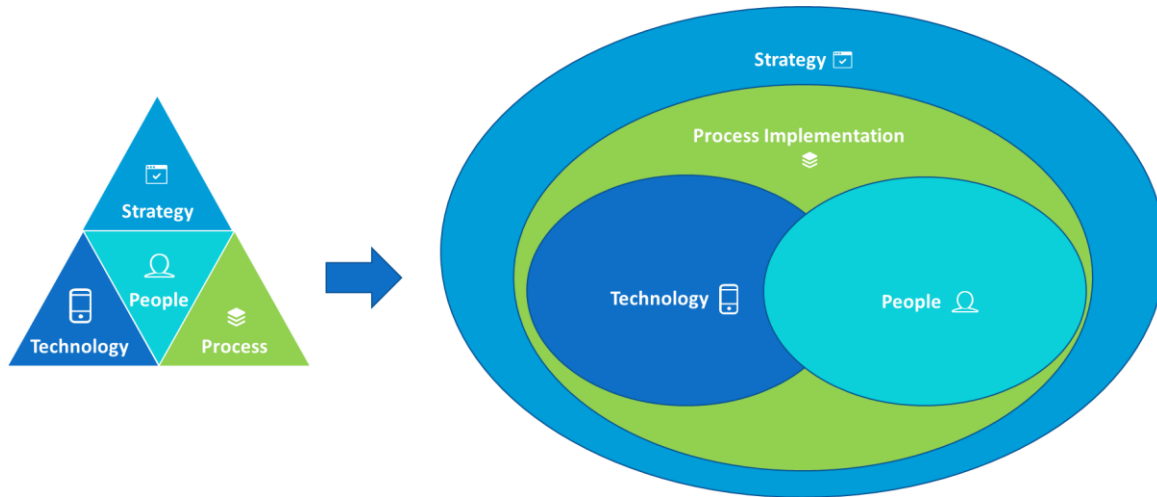
### Starting with the Building Blocks

Industry X implementation is complex, massive, and rapidly evolving. To help place structure around the topic, CAR established four building blocks: People, Process, Strategy, and Technology. Many view Industry X as a technology-driven space. However, **technology** is only one aspect that will determine success in Industry X. Without a coherent **strategy**, technology adoption often creates more problems than it solves. Overhauling the technology architecture behind an organization is no easy effort. Organizations will have to manage the entire data **process**. All of these things are complicated. Efforts will fail if not supported by the right **people**—and if the efforts do not support the people.

<sup>1</sup> Interviewees, respondents, and study participants refers to component, materials and vehicle manufacturers who were direct recipients of the CAR team's interview and survey. Stakeholders refers to broader participation, and includes the technology companies present in the project's consortium and roundtable discussions.

The research team altered the model to represent how companies reported approaching the implementation challenges more accurately. Figure [3] shows a shift to a more holistic model. Instead of pillars—or pieces of the puzzle--the four elements are much more inter-related. Strategy is the overarching driver of Industry X, but the processes used to implement technology change and empower the workforce will determine the outcomes. The report follows this model, starting with strategy, then focusing on people and technology as elements of the implementation process. Industry X will struggle without a proactive strategy. Efforts will also struggle without an effective and responsive implantation plan.

Figure 3: Industry X Project: Multiple Research Inputs

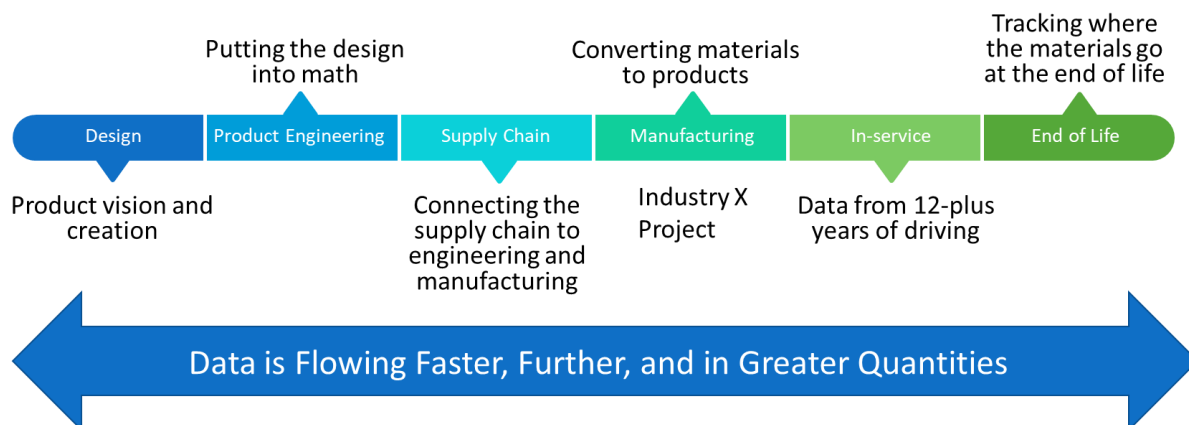


Source: CAR Research

### The Digital Continuum of Industry X

The CAR State of Industry X in Automotive project focused on the digitalization of the manufacturing process—converting materials to products. However, the data is flowing further, faster, and in far more significant quantities than ever before. And it will continue to expand rapidly. Figure [4] Illustrates how data is flowing between the traditional steps within the automotive manufacturing process. The automotive industry is racing headlong into the world of digitalization. However, the industry is fully aware that there will be mistakes along the way.

Figure 4: Industry X: Manufacturing and the Data Continuum



The State of Industry X in Automotive project focused on manufacturing. However, all stakeholders—vehicle manufacturers, suppliers, and technology companies—are preparing a world where data flows from the product vision and creation stage to the vehicles’ end of life. The data continuum offers vast opportunity for all stakeholders—and even greater uncertainty.

“We have determined that digitalization of the entire business is absolutely essential to remain competitive. We’ve made mistakes, and we’ve learned from them. We will continue to course-correct as needed, but we’re not stopping; we’re not slowing down.”

– Tier 1 Supplier

Finally, it is useful to remind readers that this research took place during the depths of a global pandemic. The project surveys and interviews were conducted between the months of August and December, 2020. For individuals involved in maintaining a production system during a massive event, such as was collectively experienced, responding to a research request becomes less of a priority. While this project took longer than had been initially expected, the participation by industry stakeholders was remarkable. Their insights, concerns, questions, and comments indicated that Industry X is a continuing priority within the automotive sector.

## Industry X: Strategy

An enterprise digital architecture, like any complex structure, requires careful strategic planning. For an architecture to provide a useful structure for a company’s business processes, it must begin with a solid foundation and appropriate framework. Such a coherent strategy is paramount for success in Industry X. Without a clear plan, technology adoption could create more problems than it solves. A strategy establishes the foundation for the implementation of technology and talent management. For most technologies, a business case dictates investment. Potential digital transformation investments may not always have a clear business case. Interviewees indicated the implementation should, at the very least, offer compelling improvement or possess potential long-term value. Creating an Industry X strategy and executing the related plans involves iterative processes that require various stakeholders’ active involvement. For example, investors, members of the board of directors, executives, employees, technology vendors, and customers will all play a role.

*“Our initial efforts [to digitalize operations] fell apart because we didn’t have a long-term strategic plan. We had to go back and design an enterprise architecture from the ground up. Without a solid foundation, the entire structure will collapse.”*

– Tier 1 Supplier

CAR researchers did not find a consistent decision-making process within companies to create, implement, and maintain their Industry X strategy. Some respondents described a specific initiative’s decision process, but it was not unusual for the decision processes to vary across the enterprise. They also described their decision processes as fluid, as their companies reorganize, reprioritize, and evolve their Industry X strategies. The Industry X decision-making process described were not straightforward because automotive companies are often large and complex corporations with multiple layers and divisions. Industry X is also extraordinarily complex and always evolving—few, if any, fully comprehend

all aspects of the change. That uncertainty reverberated throughout to project’s interviews and roundtable discussions.

For this paper, we categorize Industry X strategy into investment strategy, and implementation and scaling strategy. The sections below discuss the significant findings, challenges, and best practices identified by CAR researchers through expert interviews, roundtables, and webinars.

## Investment Strategy

Automotive industry companies are giant corporations with dozens of facilities and thousands of employees. It is a challenge to adopt an approach that encourages innovation without sacrificing efficiency. CAR research found that all of the companies which participated in this study were committed to digital transformation. Interviewees understood that Industry X adoption is a continual learning process. They considered digital transformation as a journey instead of a singular event. Many of the companies interviewed are planning and conducting brand new initiatives in this space. It was also apparent that most companies on this pathway need guidance. And some might not know—or at least are not willing to admit—that they need guidance.

The main reasons to pursue digital transformation were:

- **Better serving the customer:** Almost all of the study participants mentioned that Industry X would help their companies better serve their customers and, therefore, should positively impact their overall business. Forty-seven percent of respondents specifically mentioned a strong focus on customers. Vehicle manufacturers described vehicle buyers as their customers and prioritized providing additional value, encouraging ongoing relationships, and creating new service opportunities. Suppliers concentrated on their industrial customers up the supply chain and hosting the best methods to satisfy orders. Data was an essential element for all respondents to better serve their customers. The respondents looked towards data to form Industry X applications that could improve their products and services. However, most were inexperienced in leveraging data flows between themselves and their customers.
- **Keeping up with competitors:** Interviewees mentioned keeping with the competition as one of the primary reasons for investments. They argue that competition drives agility and the speed of adoption of revolutionary technologies. While they were confident that competition was driving implementation, they may not have understood the sophistication, or lack thereof, behind their competitor’s Industry X initiatives. Several interviewees were almost apologetic in admitting their companies were not far along on the journey.
- **Improving the bottom line:** Interviewees saw Industry X as providing a direct benefit to improving their bottom-line revenue by increasing the productivity and efficiency of Information Technology (IT) and Operational Technology (OT) processes. The CAR research team thought it was noteworthy that so few respondents focused on the importance of cost efficiencies. Often Industry X, or most any other manufacturing improvement, is sold based on increasing cost efficiencies. While increased efficiency is most certainly important, some respondents appeared to be looking at Industry X for other reasons.
- **Obtaining value from data:** Study participants saw the information generated from data analysis as a source for new revenue streams and operational efficiencies. Several participants believed they could monetize most of their data. Yet, examples of revenue generated from big data were difficult to identify. One respondent stated that “data is as valuable as the product.” Most respondents appeared to agree with that sentiment. Yet, the business models for data appear to have not matured in many cases.

- **Environmental sustainability:** Some companies have indicated that a comprehensive strategic digital transformation of business is essential to ensure its long-term financial and environmental sustainability. Other CAR research activities indicate that environmental sustainability is growing in importance for many companies, especially those with significant European operations.

For Industry X initiatives with an uncertain return on investment (ROI), companies can still justify these projects by adopting a long-term strategic vision. Ideally, these initiatives will have low downside risk while also contributing to an enterprise architecture that is adaptive, efficient, and resilient.

*“We are making healthy investments with regards digital transformation; more focus on strategy, rather than tangible payback.”*

– Tier 1 Supplier

Only a few respondents stated the COVID pandemic slowed their company’s digitalization progress due to reduced investment. About half of the respondents reported that the pandemic helped emphasize digitalization initiatives’ value, resulting in steady or increased dedicated investment.

*“COVID has energized the concept of digital transformation and partner solutions... We’ve had to change our culture to embrace remote engagement/work... We’ve been able to work well and effectively with our global partners through digital tools. We took advantage of shutdown time to work on digitalization use-cases and pilots.”*

– Automaker

When asked about recent investments in technology, nearly every respondent stated or implied that a current investment focus was building or improving their digital infrastructure. For some respondents, they were describing an enterprise digital infrastructure. For others, it was more targeted (i.e., within plants or a siloed data stream).

*“We are starting from the beginning; we are developing the foundational elements of our digital infrastructure. Most recent investment has been implementing a factory network, data historian, and analytics.”*

– Tier 1 Supplier

CAR research revealed several challenges in prioritizing investments. Below are the common themes:

- **Building partner ecosystems:** Since Industry X is a web of complex technologies, no manufacturer can implement and manage everything independently. The interviews illustrated the need for companies to form partnerships early. Without proper partnerships, some companies struggle to move past a few small projects. As mentioned in this report, Industry X is a complex implementation. Companies must do their homework in identifying partners and ecosystems. The research did not define an effective ecosystem, but it did illustrate the need for careful and thoughtful partner selection.
- **Broadening deployments and implementations:** Companies often start pilot projects in manufacturing but remain focused on manufacturing. They fail to understand that Industry X is not exclusive to this space. Additional value may come from broader enterprise implementation.
- **Scaling and global platforms:** Automakers and larger suppliers have factories across the globe. Moreover, there is the added complexity of mergers and acquisitions, cultural differences, and

different local regulations. Most companies are struggling with implementation at scale. They are finding it challenging to integrate technologies into a coherent platform that can drive results.

- **Maintaining focus:** Companies may start with the right motivations but eventually get lost in the complexities of technologies. When this happens, the business case that initiated the investment might lose focus.
- **Effectively connecting information technology (IT) and operational technology (OT):** IT and OT are two separate vertices in automotive; Industry X is merging them. Traditional automotive companies tend to consider OT as the more traditional core function. However, IT is fundamental to Industry X. Most companies interviewed are struggling to connect and coordinate their OT and IT functions.

#### Guideposts for Investment Strategy:

- It is essential for executives to establish industry an industry X vision, however those goals need be converted to understandable and actionable objectives.
- Building a flexible and proactive ecosystem throughout the Industry X value chain is vital to a success digital transformation.
- Industry X strategy must be adaptable, but companies need to keep focused on the vision.
- Industry X can effectively identify inefficiencies; but, successful implementations require a systematic understanding of the goal, not just the technology.

## Implementation and Scaling Strategy

All companies participating in the interviews expressed concern about successfully implementing Industry X technologies and processes across their manufacturing portfolio. Most—if not all—had experienced compelling proof of concept implementations, and some had even had experienced successful plant level implementations. However, the ability to leverage those gains across the entire plant portfolio was proving difficult. Industry X is transformative and introduces opportunities that were not possible before. However, the broad implementation of Industry X requires a level of system thinking that may push many companies out of their comfort zone.

Repeatedly throughout this project, respondents referred to the chasm between operations technology (OT) and information technology (IT). The challenge for digitalization efforts to reach scale is illustrative of that gap. Some described OT as being tactical—their job is to make it work on the plant floor—conversely, the goal of more broad-based strategic implementations drives IT. Industry X is forcing OT to think more strategically while making IT think more tactically (i.e., plant and process). Industry X is a journey for all companies. And for the IT, OT, and production workers, it is a shift in thinking.

Introducing a new process or technology at the plant level is often about getting the reward structure correct. The production worker and the OT department are currently measured—and rewarded—for

implementing a new process fast and effectively. To do that, they occasionally “tweak” the process. These “tweaks” can lead to different optimal solutions for each process and each plant. Because of this reward system, the OT and production workers may not grasp how changes impact the broader implementation. They are even less likely to connect their actions to broader financial targets.

Conversely, limiting variation across implementation drives the IT function. Their reward structure tends to lead them to seek a system-wide solution. But, they often do not understand the intricacies of making the process work on the plant floor. One respondent reported their company’s IT people had to be comfortable “getting grease under their fingernails.” This hands-on experience is noteworthy, but it may not be easy to find IT staff willing to make that commitment.

In many ways, the implementation of Industry X presents a paradox of perspective. This report illustrates those different perspectives. How companies respond to that paradox can impact how successful they are implementing Industry X. The CAR research team thinks it is essential to consider how companies may better adjust the reward structure to encourage a more dynamic system solution to Industry X implementation.

Through our interview with industry participants, we found a diversity of strategic approaches to Industry X. Different companies’ strategies reflect the range of distinct business models, organizational structure, corporate culture, and other factors. Within the various approaches, we identified three specific top-level themes:

### Top Down

Most OEMs and a few suppliers described their Industry X strategy as a top-down rational planning process. These companies typically adopted an “Industry 4.0” strategy soon after German industries introduced it around 2015. In these scenarios, commitment to digital transformation is quickly and fully integrated throughout the enterprise. A central corporate team determines the overall plan with continual coordination with company divisions.

### Bottom-Up

In this approach, companies financially support initiatives from the corporate level but delegate the strategy and development to targeted plants or facilities. Some companies describe a dynamic where the corporate office provides financial support but little guidance. These companies depend on specific plants and facilities to determine innovative strategies and how to prioritize technology investments. The Bottom-up model was often associated with a single individual—an evangelist or a small team of like-minded individuals.

### Middle-Out

Some companies have adopted an Industry X strategy somewhere between a top-down “command and control” model and a bottom-up “organic” approach. These companies oversee initiatives from the corporate level but have champion divisions or individuals from within the company who are directly in-charge of deployment. This model was standard among suppliers with regionalized global operations.



There are some variations to the middle-out approach. One approach is for an international corporation to task a regional office to lead Industry X strategic planning (e.g., a North American office, which may be well-positioned to leverage the Silicon Valley ecosystem and U.S. software innovation). Some companies have a dedicated division for navigating the Industry X ecosystem and have also tasked that division with managing digital transitions across their enterprise.

#### Guidepost for Implementation and Scaling Strategy:

- Industry X is transformative: Companies need to adjust the reward system to enable successful implantation
- Achieving scale is a journey. Production workers, operations technology and information technology need to travel on that journey together.
- A formal change management process is critical to success. Arrive at standards for platforms, processes, and data very early in implementation.
- Leadership should promote the culture of innovation by reducing the legacy of risk-avoidance.

## Industry X: Process Implementation

### Change is Hard

Change is hard. Disruptive change is harder. Successful digital transformation requires more than a good strategy and adequate funding. To successfully transition to Industry X, companies must be experts at process implementation. Industry X implementations fail for many reasons. Industry X process implementation involves two critical assets: the technology and the human resource/talent. Understanding the relationship between these two is essential for success in this space. Many respondents stated that an effective on-site change manager is critical to a successful Industry X implementation. The challenge of implanting change during production—or even during program launch—is daunting. Having a point person that understands the roles that technology and people play in the process can make it much more achievable.

Curiously, both assets face a legacy challenge. Many companies participating in this project were the product of decades of mergers, acquisitions, and joint ventures. The legacy workforce and machinery from these years of development plays a significant role in how these companies will move forward; and why they may struggle to do so. Regarding the workforce, the phrase “legacy” refers to operational knowledge—those with a strong understanding of rigid elements within the production process. However, it can also suggest an unwillingness to adapt to new processes and procedures. With regards to technology, legacy machinery often represents years of disjunct manufacturing tools and systems. Our stakeholder interviews and discussions confirmed that for Industry X, solving the legacy challenge is fundamental.

Industry X is often perceived as a collection of “shiny” new tools and methods for collecting, analyzing, and utilizing data. And obtaining value from machines and data will depend on skilled human operators and specialists. Meanwhile, automotive manufacturing processes have been tried, true, and trusted; which, in some cases, might diminish the excitement surrounding new practices. Successful

implementation of Industry X throughout an entire enterprise will ultimately rely on the workforce's experience, intelligence, and passion.

*"I don't care how much data is in the cloud; the knowledge is on the floor."*

– Automaker

The most impactful digitalization approaches should not revolve around reducing the need for human labor. New technologies can automate an increasing number of routine tasks. Although these tasks are being removed from desks and workstations, the goal isn't to remove humans from production processes. Instead, many respondents highlighted these instances as opportunities that empower human workers to shift their focus towards tasks where human intuition and intelligence are invaluable. At the same time, such empowerment will necessitate different and dynamic skillset for production workers.

Regarding technology, legacy systems often lead to interoperability challenges. This challenge is due to the difficulty of embedding new technology and initiatives into ongoing operations. Several interviewees expressed concern over whether complications with a digital update could potentially bring down an entire plant. While every company has a process for testing updates and adding technology, interviewees admitted to a feeling of fear in those moments when they first turn on a new digital application. Expanding the digital process beyond the plant's walls—to a sister-plant or the supply chain—magnifies these fears and challenges.

Although technology and human resource process implementation are invariable linked, the CAR State of Industry X in Automotive research team approached them as separate but closely related topics. The following sections highlight the learnings from how companies implement change for talent and technology.

## Industry X: Talent Process Implementation

### Knowledge and Skills

The interviews and roundtable discussions illustrated a challenge between an experienced, knowledgeable legacy workforce and the opportunity provided by the (younger) more technologically-savvy workforce of the future. The research also highlighted how Industry X is forcing traditional roles, relationships, and responsibilities within the manufacturing sector to evolve rapidly.

### Human Resource Skills to Acquire

New technologies are introducing new competencies and skills to workforces throughout the automotive manufacturing sector. Computer science skills, for example, are now highly sought after in many different industries. One of the automakers interviewed stated that *"we have been hiring a substantial amount of computer scientists over the past three years; they enable benefits in different business groups as well."* Computer science skills are transferable and can quickly adapt to different industries and different business areas within single companies. As industry X.0 actions encourage companies to pursue enterprise integration, they will rely on computer scientists, software developers, data experts, and other champions of the digital space.

### Human Resource Skills to Improve

As manufacturing environments become more digital, the operators who occupy these spaces and machines must adapt accordingly. Several stakeholders agreed that the role of a machine operator is evolving rapidly. Because of improved human-machine interfaces (HMIs) and advanced analytics,

modern machines can provide operators with insights into their condition and functions. With vital information like this, many of our stakeholders agreed that problem-solving skills and adaptability were important complementary traits for modern/future operators. Digital tools will ultimately empower today's workers and operators to accomplish more from their workstations. Stakeholders identified several other essential workforce traits during the roundtable discussions, and these included having a collaborative mindset and openness to change. Qualities like this are often more commonly attributed to young people, with our stakeholders describing their young talent pools as tech-savvy and beneficial to production floors.

*“Among trade talent, technical skills can be hard to come by. However, technology may help enable more technical outputs from less-technical workers.”*

*– Tier 1 supplier*

#### Guideposts – Knowledge and Skills

- Companies must engage the past and the future: "Tech-savvy" (younger) talent can support critical competencies, but the legacy workforce has knowledge that must be leveraged
- Problem-solving, adaptability, collaboration, and openness to change will be beneficial traits among future workforces.

## Workforce Change

### Industrial Technology/Operations Technology

With regards to manufacturing, digital expertise has become increasingly relevant. There has been a fundamental shift in Information Technology (IT) and Operational Technology (OT). IT represents the employees and skillsets that support a company's digital operations in a historical context, while OT represents the employees and expertise surrounding industrial equipment. Many stakeholders interviewed indicated that IT and OT are converging due to the increasing demand for digital skills throughout the entire manufacturing industry. As companies begin to expand their IT forces, it has become increasingly important for other divisions to understand their work, and vice-versa.

*“Crossing the IT/OT ‘river’ requires willingness from both sides [and] a mutual understanding of the challenges on both ends. Convergence cannot be achieved if change is only made in one area.”*

*– Automaker*

Among the stakeholders we spoke with, it became clear that there are different ways to implement this convergence within a company. Some supported the idea of keeping IT and OT as distinct units and providing each with the training to better understand how the other unit functions. Other companies indicated it is better to have personnel from each unit directly involved in the other unit's operations. An example of this offered was for an IT employee who is comfortable with “getting grease under their fingernails.” These approaches are different, but they both represent convergence at the enterprise

level. Additionally, it's essential to have appropriate executive-level guidance to determine the right direction for a respective company, based on needs and capabilities.

### Employee “Buy-in”

Employee education on new technology is a crucial factor in gaining acceptance—or “buy-in” from employees. However, buy-in comes from more than just base-level understanding. The needed level of acceptance and engagement occurs when employees understand the value and impact of implementation. Additionally, this buy-in must typically occur in multiple functions and at multiple levels within a company. The roundtable discussions with industry stakeholders highlighted the tension between Information technology, operations technology functions, and the production worker—and the need to get each group to buy into digitalization efforts:

- **Information Technologies (IT):** IT workers are typically concerned with integrating and managing new information technologies, both within IT and across different business units. But, they often lack understanding (experience) of the complexities of implementing systems in a highly dynamic manufacturing environment. Many stakeholders discussed the importance of having the IT workforce thoroughly understand their manufacturing operations. However, finding IT talent that appreciates the structure of manufacturing is difficult.
- **Operations Technologies:** OT workers are typically tasked with integrating Industry X technology into the production system and ultimately managing it throughout the lifecycle. Legacy OT employees are often not savvy or concerned with rapidly evolving IT processes. Many respondents indicated the OT workforce is becoming more IT savvy—but the rate of change in information technology makes it difficult for them to stay up-to-date.
- **Production Workers:** The shop floor is usually where the most resistance, tension, and drama can happen. Production workers are usually the ones whose day-to-day tasks are most directly influenced by technology. In addition to understanding how the technology operates, workers also want to know precisely how the technology will impact or influence their current work—especially any potential for job loss. While there was some disagreement regarding the reluctance of production workers, many echoed the supplier who stated there is significant implementation risk in shop floor staff being resistant to new technologies. According to the stakeholder, resistance can come from distrust (years of new technology failures) or fear of obsolescence (i.e., fear of job loss).

*“The technology” is not real until they see it. Assembly workers, especially in the U.S., must be convinced of the value and benefit of any innovative technologies”.*

*– Tier 1 supplier*

While many C-suited executives may not deeply understand the complexities and vagaries of their OT-IT relationships and operations, their leadership can (positively or negatively) affect Industry X implementation. Some of our respondents stated their digital transformation initiatives began at the C-level. A clear, thoughtful vision from the C-suite gave the OT and IT a “North Star” to follow. Without a “North Star”, it can be challenging to get everybody moving in the right direction.

### Guideposts for Workforce Change:

- Information Technology (IT) and Operational Technology (OT) are converging.
- Buy-in for any new initiative occurs in different sectors, stages, and executive levels, within a company. Communication across all levels can speed implementation
- Understanding the implications of an initiative is critical to achieving buy-in.

## Capabilities

### Skills Gaps

Alongside any perceived benefits, digital transformation introduces new environments, protocols, and tools to engage workers. Advancing these initiatives often requires some form of education, especially among established workforces. One supplier that we spoke to claims that their *“average operator is in their early 40s and has been doing things the same way for way too long.”* Another supplier suggested that manufacturing processes can only be improved and automated if operators are adequately trained and equipped to work in conjunction with related technology. These comments point to a symbolic gap that exists as the distance operators must “travel” from their current routines and expertise towards successful Industry X implementation. The research team spoke to several companies with established internal education initiatives to help current employees understand and engage incoming technologies. One supplier had created an in-house apprenticeship program to promote digital competencies among interested employees. An automaker described another internal program, which pairs “legacy workers” with newer employees, to promote simultaneous learning.

### Talent Attraction and Retention

Internal education and training are valuable components to digital transformation, but some skills and expertise are difficult to develop within a workplace. Improving a company’s digital competencies should also be realized by hiring new talent. One automaker stated that *“the technology is changing faster than our people,”* adding that *“our maintenance staff hasn’t even seen some of the new technologies coming in.”* Hiring new talent can help companies avoid falling behind in specific competencies. However, the stakeholders highlighted some complications with this approach. One supplier mentioned that much of their manufacturing occurs in low-cost countries, where it can be challenging to obtain and retain highly skilled or specialized workers. There are similar difficulties within the U.S. regarding digital experts, where our stakeholders described competition with companies in Silicon Valley and other tech hubs. One automaker claimed that it could provide competitive compensation for its incoming and current IT workforce, recognized that other manufacturing companies may not have the budget to compete for their desired candidates. One supplier sought to obtain desired competencies among young talent; they’ve been involved in hackathons and STEM activities at local universities and high schools to increase awareness. Another supplier stated they were not interested in competing for talent and couldn’t develop their own digital assets. Instead, this supplier is investigating ways to partner with startups and software companies who specialize in their specific needs. Despite having different methods for obtaining and retaining new talent, most stakeholders similarly described new skills and benchmarks for their future workforces.

#### Guideposts for Capabilities:

- Employees will need to be increasingly flexible to navigate constantly evolving process change.
- Companies must balance talent strategies. Training current staff is fundamental to successful implementation of Industry X. Selective hiring of new skills can open innovative frontiers and opportunities.
- Effectively identifying new production and technical skillsets will define success for future hiring.

## Industry X: Technology

The vision of Industry X is to achieve a coherent digital architecture across all business and production processes throughout an enterprise. While some of the automotive companies interviewed described this as a long-term vision, it's challenging to identify precisely where a company stands. The concept of a complete and coherent enterprise architecture may be useful to inform strategies and guide investments but is likely not achievable for every corporation. The real world is too messy.

Modern corporations are complicated agglomerations of multiple processes and cohorts, often including merger or acquisition elements and having unique cultures, practices, and technology solutions. While Industry X investments should always consider long-term integration within an enterprise architecture, companies should also use use-cases with proven near-term return on investment.

A comprehensive Industry X strategy incorporates a broad range of potential technologies. Digitalization aims to implement technologies that serve a specific purpose and rationally integrate those into a viable enterprise architecture. The specific technologies that companies choose to invest in can vary based on a company's product lines, business model, customers, and other factors.

Yet, as noted several times in this report, it is a difficult challenge. Not Surprisingly, several of the individuals interviewed noted that at least one significant digital technology deployment effort of the company was unsuccessful and abandoned. One interviewee described it as, "We went too far too fast." There are many reasons an Industry X initiative might fail. Sometimes, companies cancel programs because they did not fit well within a comprehensive enterprise-wide strategy. While unsuccessful, these "failures" may be valuable learning opportunities. Several interviews included discussing the challenge of accepting failure in such a high-volume and risk-averse manufacturing business like automotive. Automotive manufacturing investments are substantial; therefore, the cost of failure can be huge.

CAR researcher conducted long-form interviews with representatives from six vehicle manufacturers and 11 suppliers. During the interviews, the CAR team inquired about the companies' implementation process for technologies.

The structured interviews opened with a question intended to *identify the technologies that automotive manufacturers have been targeting* through recent and ongoing investments. Companies responded to this question in a surprising range of ways:

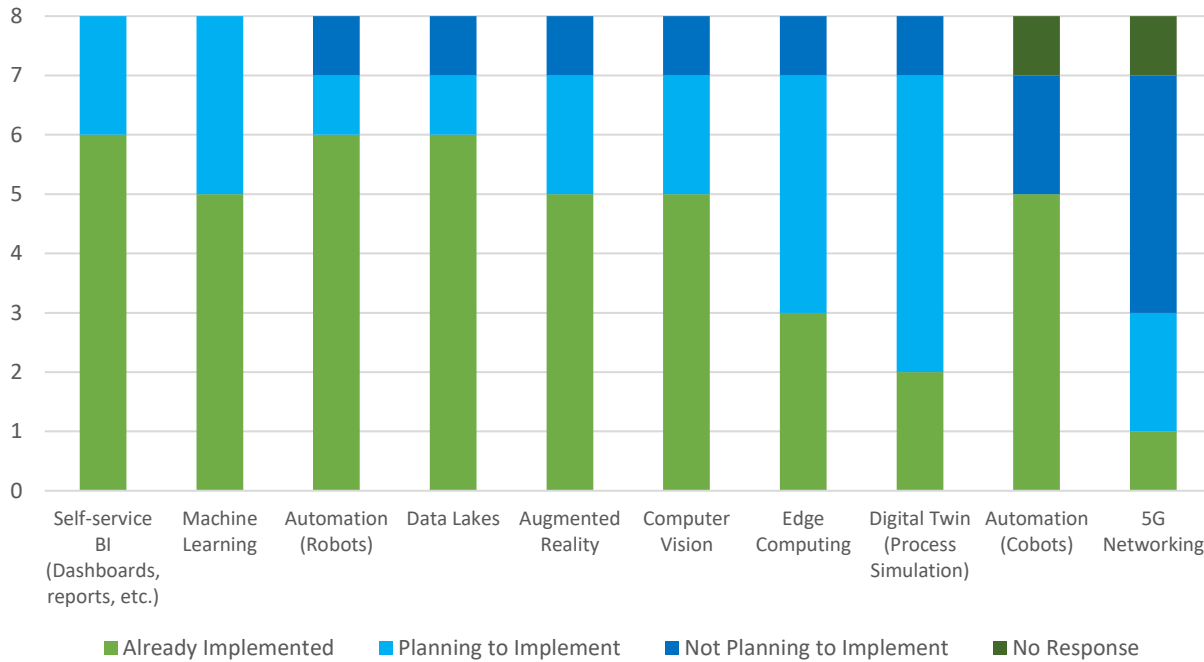
- Several companies mentioned specific small-scale demonstrations or proof-of-concept (POC) projects that they had not integrated into core operations. Examples of these point solutions include:
  - 3D printing
  - Inspection drones
  - Cobots
  - Smart gloves
  - Innovation platforms
- A few companies focused on establishing an over-arching business structure and data architecture to allow plant-level operations and data to integrate across the enterprise. Examples of these basic platform capabilities include:
  - Basic system design
  - Plant networking
  - Sensor retrofit
  - Cloud storage and compute capacity
- Some companies described investments or acquisitions they had recently made in smaller technology companies specializing in industrial automation, machine learning, machine vision, and data analytics. Some described innovation partnerships with other distinctive companies.
- Several companies emphasized efforts to upskill their workforce for digitalization through training and hiring programs.
- Other respondents used this opportunity to describe general strategic priorities or accomplishments.

## Recent and Ongoing Technology Investments

To further identify specific technology investments CAR distributed a follow-up, multiple-choice web-based survey to interviewees. The primary intent of asking multiple-choice questions in a web survey was to force respondents to provide more definitive answers. The survey focused on companies' adoption of technology (e.g., machine learning, augmented reality, cobots), and implementation of application processes (e.g., predictive maintenance, factory energy management, supply-chain optimization).

While only a small sample, the survey responses can provide a unique insight into automotive Industry X adoption when combined with insights from the structured interviews and round table discussions. The results of this survey regarding digitalization technology adoption are provided in Figure [5] below.

Figure 5: To What extent has your organization adopted the following technologies?



Source: CAR Research

Interview results and roundtable discussions can add additional context to the survey results, as discussed below.

**Self-service Business Intelligence (BI):** Self-service BI was tied with performance monitoring for the most popular technology investment among survey respondents. Seventy-five percent of respondents’ report having already adopted this, with the other twenty-five percent planning on adoption. Structured interviews found that many automotive companies have ideas about how to link production data with business analytics. Still, only a couple claim to have activated such a program and did not divulge details.

**Machine Learning:** Sixty-three percent of survey respondents report having already implemented machine learning, with the remainder intending to do so. The interview results suggest that machine learning is a point of interest and confusion for companies. Most are excited at the potential for machine learning to provide valuable insights regarding a range of processes but are often confused about pursuing implementation. Some interviewees may have unrealistic expectations for machine learning to provide value without expert humans to guide the implementation. To paraphrase one Tier-1 respondent, *“Our goal is to collect as much data as we can and let the AI figure out what is valuable and how to use it.”*

**Automation (Robots):** Seventy-five percent of survey respondents report having implemented automation in production facilities. This is most commonly industrial robotics integrated into the production line, but some interviewees noted that recent investments included automated guided vehicles for component distribution within plants. Only thirteen percent of survey



respondents have not, and do not plan on, adopting robots within the production process. Another question within the survey asked if companies had implemented “equipment and process automation;” in this case, only fifty percent of respondents’ report having already implemented, twenty-five percent less than robotic automation in general.

**Data Lakes:** Seventy-five percent of survey respondents report utilizing one or more data lakes. Of those who are not currently using data lakes, half intend to adopt this in the future. The structured interviews did not include a specific question about data lakes, but a few interviewees mentioned including data lakes in their data architecture. One interviewee stated that they were currently using Hadoop for this but thinks they will probably migrate to the cloud in the future to allow for scaling. The overall impression from interviews is that data lakes are often an interim step to future data analytics that have not yet been implemented.

**Augmented Reality:** Sixty-two percent of survey respondents report having already implemented augmented reality (AR), with an additional twenty-five percent planning to. A separate survey question found that eighty-eight percent of respondents have adopted or plan to adopt augmented reality for worker safety and productivity. Interview findings suggest that companies have had varying success in implementation. One company stated they recently ended an AR program because it was unhelpful. Another company reported successfully implementing “AR lite,” and described a training module where an instructor demonstrated how to operate a machine while wearing a camera on their head. The company then used the videos to train workers at remote facilities.

**Computer Vision:** Sixty-two percent of surveyed companies report having implemented computer vision. Only thirteen percent of companies do not plan on implementing computer vision. The most typical application for computer vision is automated reactive quality inspection. One Tier-1 supplier stated an interest in using it to measure worker productivity, and a couple of others to aid worker health and safety. In a separate survey question focused on employee safety and productivity, thirty-eight percent of respondents reported planning to implement computer vision for such applications.

**Edge Computing:** Thirty-eight percent of survey respondents report having implemented edge computing. Only thirteen percent are not planning to implement. One interviewee whose company was planning to implement edge computing stated that this was most interesting for plants in regions with unreliable or low-bandwidth internet connectivity. Other interviewees who discussed edge computing were often unable to articulate how it fits into a broader architecture. Understanding of this term appears to vary between stakeholders.

**Digital Twin:** Twenty-five percent of survey respondents report having already created a digital twin of one or more production processes. Only thirteen percent of respondents do not plan on doing this. Interviewees described pursuing digital twin as a precursor for enabling further digital operations such as remote monitoring and perhaps even remote operation. A few interviewees noted that they would eventually like to extend digital twin across the entire plant, though none of the companies we spoke with approached such sophistication. A separate question of the survey asked about digital twin, specifically in the context of process design. This question’s response was more positive, with all respondents reporting interest and half reporting to have already implemented.

**Collaborative Robots:** Sixty-three percent of survey respondents report having acquired collaborative robots (“cobots”). The interview series asked specifically about cobots, and many interviewees indicated that these tended to be limited pilot projects. A couple of interviewees noted that finding appropriate uses for collaborative robotics was difficult. One interviewee stated that they were now “collecting dust in a corner.”

**5G Networking:** Twenty-five percent of survey respondents have provided a 5G network in one or more production facilities. An additional 25 percent indicate that they plan to, but a surprising sixty-three percent of survey respondents state they do not intend on implementing 5G. The interview results reflected this disinterest as very few interviewees mentioned 5G even though many of them stress the importance of backbone network architecture. Automotive manufacturers may not yet understand or appreciate the advantages of 5G over more established networking technologies.

#### Guidepost for Technology Adoption:

- Companies must take time to understand the technology behind “the technology” —Never again invest in technology for “technologies sake
- Consider how technologies fit within a broader enterprise architecture and strategy.
- The legacy workforce has knowledge gained through years of experience. Leverage their know-how to better fit Industry X technologies into the production system.

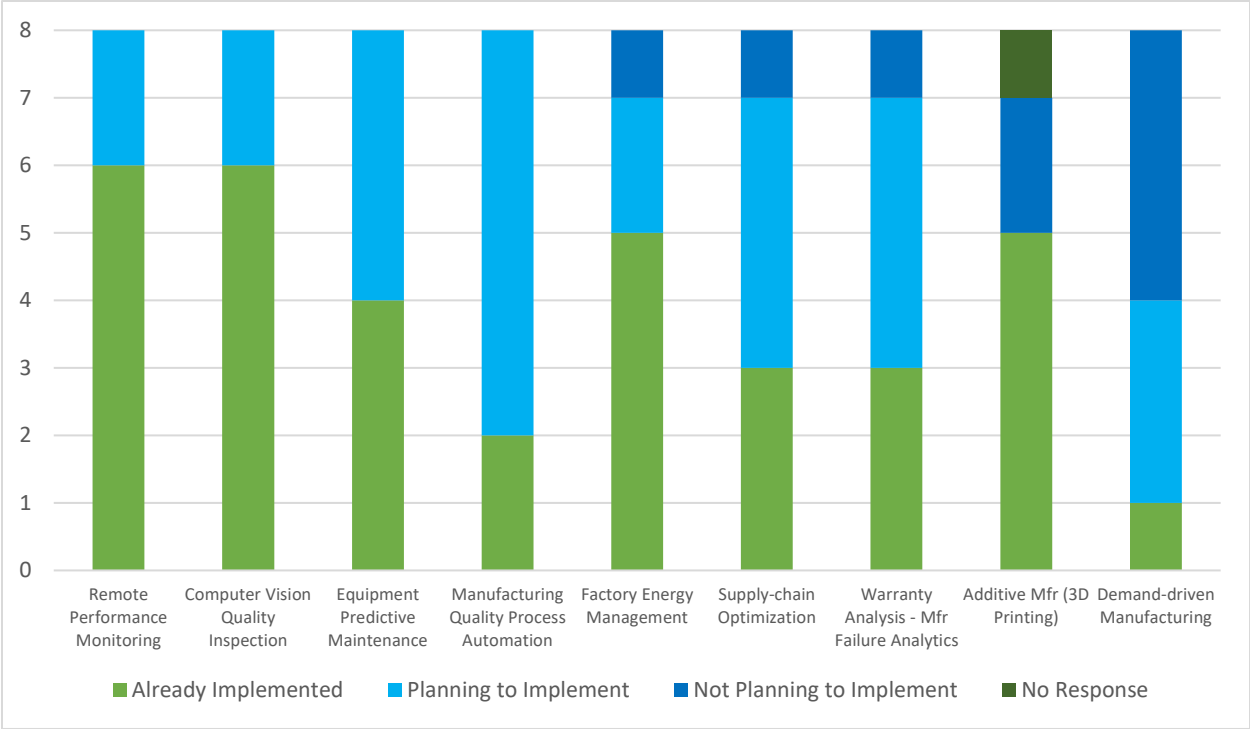
## Priority Applications and Processes

Industry X’s priority is to identify inefficiencies in production and business processes across the enterprise and leverage appropriate technologies to address those inefficiencies. In the structured interviews, the research team sought to identify the specific processes and use-cases on which automotive companies are focusing. The most pertinent line of inquiry opened with the question, “Can you describe the data-based processes that are critical to your business operations.” Similar to the findings surrounding technology investments, the detail divulged level varied widely and didn’t reveal much overall. The majority of the respondents seem to have interpreted this question as focusing on data processing abstractly; initial responses typically described the importance of data collection, cleansing, and structuring required before performing any analytics.

Follow-up prompts to the process question attempted to identify the specific application processes (i.e., manufacturing and business processes) from which the companies collect data. Additional questions and prompts throughout the structured interviews provided interviewees with additional opportunities to describe specific use-cases and how digitalization can benefit. Across the range of questions and prompts, the team achieved some success in drawing-out details regarding use-cases. However, success was limited by similar complications discussed in the previous section. A further complication is that most interviewees did not distinguish between the technologies they were investing in and the processes to which those technologies were being applied. When asked about use cases, some interviewees provided more examples of POC pilots or general references to broad strategic priorities.

As noted previously, the follow-up web-based multiple-choice survey investigated both technology investments and application processes implementation. The results of this survey regarding application processes implementation are provided in Figure [6], below.

Figure 6: To what extent have you implemented the following application processes?



Source: CAR Research

Interview results and roundtable discussions can add additional context to the survey results, as discussed below.

**Remote Performance Monitoring:** Seventy-five percent of survey respondents reported leveraging digitalization to enable remote performance monitoring of production systems. During the structured interviews, none of the interviewees offered detail on a specific production line or process, possibly because this application is being adopted to multiple unique processes across the company.

**Computer Vision Quality Inspection:** Seventy-five percent of survey respondents report implementing computer vision for quality inspection, with the remainder planning to do so. There are multiple known examples of successfully implemented computer vision being quality control. In interviews, most companies highlighted this as an application that has already seen success and promises to be further implemented across more processes. This is one of the few applications that interviewees could state with some certainty had resulted in positive ROI where investments. However, interviewees often seemed reticent to discuss specific implementations. This may be related to a lack of familiarity with individual plants’ detailed operations or hesitancy to divulge information regarding a perceived competitive advantage. An interesting finding of the survey is that when respondents were asked about the general adoption of computer vision technology, sixty-two percent reported having invested. However, when asked about a specific computer vision application for quality inspection, seventy-five

percent answered affirmatively. It is difficult to understand how respondents were interpreting these questions such that their answers are consistent.

**Equipment Predictive Maintenance:** Equipment predictive maintenance was the most mentioned digitalization application mentioned across the structured interviews. The survey results back this up by finding that seventy-five percent of respondents have implemented it, with the rest planning to do so. Some interviewees admitted that while they have implemented predictive maintenance applications by retrofitting legacy equipment with sensors and networking, they still collected data and tuned the algorithms and reporting procedure to benefit from it. Other interviewees were confident in reporting that predictive maintenance had been successfully implemented at scale but did not provide detail. One exception is a large supplier who reported that vibration sensors retrofit to cooling fans could predict failure with 95% accuracy. The supplier was confident that the project returned a positive ROI with a high multiple but was unsure of the exact figure and hinted that it might be challenging to calculate in any case due to all the factors involved.

**Manufacturing Quality Process Automation:** Only 25% of survey respondents having implemented manufacturing quality process automation, but the remainder intends to do so. This application was defined within the survey as utilizing data and machine learning to proactively identify and monitor factors driving sub-optimal quality outcomes. It is somewhat surprising that any survey respondents reported having implemented this; the interview series found that many manufacturers were enthusiastic about this application but were still a few steps away from activating this across an entire production process. Survey respondents may have interpreted this to mean a more limited application such as quality control.

**Factory Energy Management:** Sixty-three percent of survey respondents report already implementing factory energy management. Twenty-five percent plan on doing it and thirteen percent are not interested. Several interviewees mentioned the concept of “smart factory,” but these tended to be the more high-level interviewees and provided little detail. One automaker mentioned implementing a “smart factory” and provided some detail focused on sensor-based HVAC controls.

**Supply-chain Optimization:** Thirty-eight percent of survey respondents report having implemented supply-chain optimization. This result is somewhat surprising in the context of interview findings. Many companies emphasized gaining more insight into and controlling their supply chain, but most indicated they were in very early stages. On the other hand, if the survey question was interpreted broadly, it could include many smaller targeted initiatives that don't necessarily optimize an entire supply chain but may improve transparency and efficiency. It is also surprising that thirteen percent of survey respondents indicated having no plans for supply chain optimization. All interviewed companies produce a relatively large variety of products, many complex and high-value. The logistics of these production processes are substantial and must offer multiple opportunities for cost savings through improved efficiencies. One finding of the interview series is that some suppliers—while desiring transparency of their supply chain—were not interested in offering transparency to their customers. In part because of the challenges presented when multiple customers request different data types in different platforms with different formats. Suppliers are also concerned that the optimization of a supply chain by their customers may come at the expense of their profitability.

**Warranty Analysis (Manufacturing Failure Analytics):** This use case was defined in the survey as implementing a system to “identify and correct product defects using production and consumer data.” Thirty-eight percent of survey respondents report having already implemented warranty analysis. This finding is surprising in relation to the interview series, as—similar to supply-chain optimization—several companies discussed an interest in implementing such a process. Still, none indicated that they were anywhere close to doing so. The complexities around getting enough consumer data to make this viable were typically considered a considerable hurdle. One possibility is that survey respondents did not read the provided definition and interpreted this in some other way, such as some general process targeted at fault analysis. Most remaining survey respondents plan to implement this, with only thirteen percent not planning to do so.

**Additive Manufacturing (3D Printing):** 3D printing seems to have mostly completed the hype cycle among automotive manufacturers, having now been established as a useful technology with applications currently more limited than initially imagined. Sixty-three percent of survey respondents report having implemented 3D printing. The remainder do not plan to do so. The interview series supported previous CAR findings on 3D printing; it is a useful technology for rapid prototyping and part replacement, but not scale manufacturing. One interviewee also complained that 3D printer manufacturers attempt to hide costs through markups in materials and service fees and such.

**Demand-driven Manufacturing:** The survey results indicate this to be the least targeted application of digitalization, with half of the respondents not even intending to implement it. Demand-driven manufacturing was defined in the survey as the “monitoring [of] demand (vehicle and consumer) patterns to optimize downstream manufacturing resources and inventory.” On the one hand, it is surprising that even thirteen percent of respondents’ report having implemented this as the structured interviews identified getting downstream use-data of manufactured products as an exciting possibility, even a priority, but one that has not yet been realized. On the other hand, the respondents may not have read the definition; *all* manufacturing is demand-driven to some extent.

#### Guidepost for Technology Applications and Processes:

- Companies are struggling to understand Industry X technology process implementations. As a starting point, consider how technologies fit within a broader enterprise architecture and strategy.
- In refining Industry X technology implementation plan companies must look beyond the technology and consider the process and people.

## Conclusions

For this project, the CAR research team extensively examined how key industry stakeholders view Industry X. Based on interviews and roundtables with a diverse group of Industry X stakeholders, the State of Industry X in Automotive research identified several critical conclusions:

- **Industry X is Really Difficult:** Industry X implementation is complex, massive, and rapidly evolving. It quickly became apparent that few, if any, companies can navigate it alone. While the research did not identify the most effective ecosystem—and many models described during the interviews—companies are exploring how best to leverage needed knowledge and technology.
- **Most companies are (mostly) “all in”:** The interviewed companies are focused on digitizing manufacturing and production. Regardless of a range of strategies and approaches, digitization is a priority across the companies interviewed for this project.
- **Industry X drivers differ:** The most common reasons given to pursue digital transformation were keeping up with the competitors, better serve the customer, improve the bottom line, and monetizing data.
- **ROI is not always obvious, but that is okay:** It is often difficult to calculate a return-on-investment (ROI) for digitalization initiatives. The challenge is particularly real at the beginning stages, where the focus is on experimental proofs-of-concept or installing basic digital infrastructure. The difficulty of calculating an industry X investment ROI should not be interpreted as the project lacking value. Such confusion reflects the rapid pace of technological change. Industry X digitalization is likely to revolutionize manufacturing and production in various ways that are yet unknown. Investments made now in basic infrastructure and expertise may be necessary prerequisites for a business to thrive and even survive in the years ahead. The maturity of Industry X adoption varies widely across companies, from those with a coherent digital enterprise architecture in a late stage of deployment, to companies that have only recently begun planning for digitization in earnest. Understanding that it is a journey and that most industry participants are struggling on the path is essential.
- **No matter who leads, a flexible strategy is necessary:** Enterprise-wide implementation Industry X is most successful if driven by executive and board buy-in. However, whether Industry X is driven by a top-down, middle-out, or bottom-up process, a coherent, flexible strategy is paramount for success. That strategy should establish the foundation for the implementation of both technology and talent management.
- **There is value in the data:** Companies are looking towards Industry X to facilitate new revenue streams and efficiencies from the data created during production and/or the use of their manufactured goods. The general theme presented by respondents is that the data is becoming as valuable as the product. However, in most cases, that value has yet to be realized.
- **Early Implementations need to be tailored:** For many manufacturers, Industry X strategy is often necessarily abstract and lacking detail. Initially, implementation details are tailored to various divisions and facilities to best complement those facilities’ attributes. But, this tailoring is a problem for systems optimization.
- **Moving from proof of concept to scale is transformative:** But that step is a journey. The process brings opportunities that were not possible before. However, the broad implementation of Industry X requires a level of system thinking that may push many companies out of their comfort zone. The CAR research team thinks it is essential to consider how companies may better adjust the reward structure to encourage a more dynamic system solution to Industry X implementation.
- **OT and IT are fusing:** Industry X’s success requires the unprecedented blending of IT and OT expertise, as well as hands-on experience. Companies should take care to achieve understanding and build a reward structure that encourages collaboration.

- **Legacy systems present a *challenge*:** Modern corporations are complicated collections of multiple processes and technologies, often including merger or acquisition elements. Their operational systems reflect that heritage. Implementing digital transformation over multiple manufacturing systems is fraught with barriers.
- **Legacy people present a *dilemma*:** New technology often perplexes legacy workers. Respondents frequently commented about the opportunity provided by a younger, more tech-savvy workforce. However, built into the legacy workforce is a generation of process knowledge and understanding. Companies face the dilemma of melding the experienced workforce’s strengths with the next generation’s technology savviness.

Automotive stakeholders are moving beyond merely chasing “shiny” new technologies to something more systematic and powerful. But, they are still early on that journey—very early. Implementing Industry X presents a *paradox of perspective*. Digital transformation requires a level of coordination, cooperation, and communication that makes many companies uncomfortable. It connects people and functions in ways they have never been before. On the surface, Industry X is a technology-driven concept. However, this report illustrates it to be about transformative change. At its core, this change is about the people: From the C-level to the information technology and operational technology implementors and the production floor workers, Industry X requires a willingness to change. And change is difficult.

## Appendix A: Methods Interview and Survey

1. “Is your company digitally transforming your manufacturing processes? If yes, Why?”
2. “Could you talk about any recent or ongoing investments your company has made in digital technologies?”
3. “What is the decision-making process at your company regarding these kinds of technology investments?”
4. “What is the outcome or current status of [use case(s)]?”
5. “One focus of our research is to identify innovative ways that data is being utilized; can you describe the data-based processes that are critical to your business operations?”
6. “How much do your core business operations depend on physical paper documents and records versus electronic record keeping?”
7. “Could you describe how different technologies and processes are integrated across [company]? (E.g., Is there an enterprise network or a combination of individual solutions?)”
8. “Please give us a sense of what kind of knowledge and skills are critical in making these technologies work for your business operation? Are there challenges in obtaining the right people?”
9. “What kind of business upgrades is your company considering in the near future? (and, why are you looking at these options?)”
10. “Has [company’s] strategy or general thinking about technology investments been impacted by the COVID-19 pandemic?”
11. “What kind of emerging trends or developments regarding digital manufacturing technology are you tracking or otherwise interested in?”
12. “What didn’t we ask about the future of manufacturing technology?”



## Appendix B: Roundtable Summaries

### Roundtable - Strategy & Technology

On October 21, 2020, the Center for Automotive Research (CAR) hosted a roundtable discussion attended by experts in the automotive manufacturing space to discuss the strategy and technology involved in digital transformation. Some key takeaways and suggestions include:

- Simplify and necessitate data-sharing throughout supply chains.
- Partnership and cooperation are critical factors for success.
- Navigate facility/operation/enterprise transformation with a focus on continual improvement and openness to readjustment.
- Develop early standards for new processes and platforms.
- Strive for compatibility and interoperability.
- Only focus on technology that's best suited to your business and desired outcomes.

This roundtable started with a high-level overview of the project's interview findings. Attendees were then presented with several prompts to respond to before diving into broader discussions quickly:

#### **What needs to be true to achieve the strategic goals for digital transformation? And how will we know that we've achieved them?**

Attendees listed out several immediate responses to the question. The answers were then categorized into several categories:

- **Digital Infrastructure** – It is essential to host an adequate digital infrastructure, including edge computing capabilities to bridge Information Technology (IT) and Operational Technology (OT).
- **Leadership Buy-in** - Support from executive leadership is important and appropriate knowledge and tools within these groups.
- **Ownership** - Plant operation teams need to feel a level of ownership of their systems to enforce meaningful data entry.
- **Business Focus** – It is important to prioritize capabilities and always strive to obtain greater enterprise value.
- **Definitive Business Cases** - Strategic goals should be broken down into actionable objectives, which can demonstrate progress and a general direction.

During the broader discussion, a key point was made about a differentiating factor among the lead companies. One of the attendees stated, "For companies that are winning, they think about their infrastructure differently. Partnerships and cooperation with other entities is a key to success in this space." This comment drove the discussion towards additional related questions and discussions. Other comments stressed the importance of data governance; a tier-1 supplier claimed that "If data is not standardized and governed, [an initiative] will ultimately fail... this will require organizational changes".

Follow-up comments and questions revolved around conservative and generally "rigid" automotive industry culture. One technology provider mentioned that their business is aware of the high-stakes and risk-avoidance tied to automotive customers. The company also noted that many of these

customers' projects tend to focus on existing operations. Attendees then discussed the ways change can be introduced to an otherwise rigid and traditional industry. One automaker and one supplier both described a similar focus on continual improvement and openness to readjustment; this strategy has helped both companies progress in their digital transformation objectives. A follow-up comment pointed out that innovation often occurs gradually due to interdependencies in the auto supply chain: "It is not just one party/vendor that needs to innovate, the entire ecosystem needs to innovate".

### **What are the important strategic steps to integrate digital transformation through the supply chain?**

Attendees listed out several immediate responses to the question. The answers were then categorized into several categories:

- **Value-added throughout the supply chain** - Identify the entire integrated system's value, the data must be meaningful for all parties involved.
- **Data definition** - Create guidance and instruction on how data is accessed and used throughout the entire company.
- **Architecture** - it is crucial to rethink traditional architectures (ex. Establish a data plumbing infrastructure first).
- **Implementation considerations** - Consider standards and governance early and reduce the number of steps towards deployment/orchestration.

Next was another broader discussion related to the prompt and initial responses. One automaker stated that among its supply base, data should be meaningful to the supplier capturing it. A supplier made a follow-up comment about the complexities that arise with capturing data: "We have many OEM partners. Even if I choose to share my data with one OEM, there is additional complexity driven by the fact that every other OEM is utilizing and accepting data differently".

One of the project funders stated that "[We] need to rethink these traditional architectures that have been around for so long. We want designed and engineered architectures built around current tools and data." Some attendees proceeded to discuss and describe the importance of establishing early standards for new processes and platforms. Early standardization is an excellent way to remove waste and complexity from developing systems.

## What roadblocks does technology create?

Attendees listed out several immediate responses to the question. The answers were then categorized into several categories:

- **Implementation** - Some technology is being quickly developed and sold with complex troubleshooting—also, the speed of deployment/implementation matters.
- **Standardization** - Standards are good but can also impede future innovation when based on past issues.
- **Technology advancements** – It is difficult to understand every technology pitch. Investment to connect legacy systems can be a difficult decision. Cheaper technology “tomorrow” might discourage investment “today”. Technology is evolving very quickly, so skill sets need to be more adaptable
- **Data** - An overwhelming amount of data available, as well as data silos and duplicate data.
- **Data sharing** - Data sharing across supply chains is not standardized, and barriers exist— interoperability and upgrading systems across the enterprise.
- **People** – Leadership’s response to implementation failures and fear of the unknown is crucial. There will be failures.
- **Value articulation** - CAPEX to OPEX.

The first few points of the broader discussion revolved around the concepts of integration and interoperability. Regarding integration, one automaker claimed that they will not integrate anything that is not already compatible with its enterprise. On the interoperability topic, one of the project’s funders claimed that they decided to standardize around a core enabling methodology years ago. They are still working to “wean” some of their clients off of older/contradicting systems for this funder.

The discussion then shifted towards the speed of evolution in the technology space. A technology supplier stated, “Technology evolves very quickly, that is part of a technology company’s role. When you look at the technology skill sets necessary to keep up, things aren’t moving that fast”. The technology supplier followed this by suggesting that companies need to focus on what’s relevant to their business to achieve their desired outcomes. As a digital solutions provider, the same company provided further insight into working with small-medium companies compared to larger clients: “Frequently the smaller companies look at [our packaged solutions] as a desired competitive advantage. The bigger companies move much more slowly with regards to transformation”. A follow-up statement claimed that digital transformation initiatives are only valuable if they can be successfully integrated across an organization. This claim led to a mention of the eventuality of an “as-a-service” option for digital and IoT solutions. A technology supplier responded by mentioning that “IoT-as-a-service” is becoming more valid as the ability to pay-for and integrate tools gets faster.

## Roundtable - Process and People

On November 11, 2020 the Center for Automotive Research (CAR) hosted a roundtable discussion attended by experts in the automotive manufacturing space to discuss the people and processes involved in digital transformation. Some key takeaways and suggestions include:

- Digital infrastructure may be challenging to implement and/or uphold in low-cost labor regions.
- With new and emerging technology, individual machine operators can accomplish more from their stations.
- Most companies are still figuring out how to navigate their data.
- Good communication between affected teams and executives is crucial for understanding an initiative's feasibility and potential value.
- Several different enablers (of digital transformation) can exist within a company.
- Information Technology (IT) and Operational Technology (OT) are converging.

This discussion started with a high-level overview of the project's interview findings. Attendees were then presented with several prompts to respond to before diving into broader discussions quickly:

### What are the skills for industry X.0 implementation, and how do you develop them?

Attendees listed out several immediate responses to the question. The answers were then categorized into several categories:

- **Workforce** - Establish a culture that promotes collaboration, problem-solving, and openness to change.
- **Technology** – It is important to have software-driven skills, empowered by modern tools and infrastructure.
- **Talent management** - Finding a balance between training and hiring new talent. Companies are competing with Silicon Valley for highly-skilled workers while also enabling line workers to engage in higher-value activities.
- **Data management** - Important to develop skills in machine learning, and data management.
- **Scaling** - Design for repeatability and scaling.

During the discussion, a supplier mentioned some notable complications: “A lot of our manufacturing is in low-cost countries so there’s no cookie-cutter solution for our processes. The challenge with new technology exists in finding the balance between costs, safety, and practicality. There may be a toolbox of technology that our plants can use, but it doesn’t make sense to force them to use it”. This supplier also pointed out two problems in finding and obtaining talent in low-cost countries. One issue is a generally low number of highly skilled operators and technicians to engage with new technologies. The other issue being increasing competition for labor in low-cost countries. These points helped reinforce an urgency to adapt workforces to innovations in manufacturing. Another related discussion revolved around the future experiences of machine operators. A supplier stated that they’re “looking to enable [operators] with problem-solving skills to engage with smart assets”. Many attendees agreed that machine operators will generally be able to accomplish more from their stations, with technology that provides robust insight into machine conditions and function.

## What is necessary to get the data from the plant floor to the point of use?

Attendees listed out several immediate responses to the question. The answers were then categorized into several categories:

- **Data strategy** - Establish a long-term strategy, which considers both legacy and new machines. Establish new storage domains, enterprise-grade edge computing.
- **Standardization** - Establish standard and consistent interfaces and data formats. Build an IT/OT standard infrastructure.
- **Interoperability** - Enable 2-way flows for data and information.
- **Secure channels** - Establish Software-defined networking (SDN) and Software-defined data centers (SDDC). Ensure data is secure and avoid risks.
- **Legacy** - Upgrade or replace legacy systems.

The broader discussion included additional attendee comments on their experiences and observations with regards to working with data. One attendee claimed that, for them, “data is still coming together into serviceable utilities. It’s not universally available at this point, but there are focused areas and use cases where we’d like to apply it”. Other attendees agreed with this sentiment; most companies are still learning how to navigate their data. One of the funders commented that it’s essential to have data specialists involved in data initiatives from the very beginning. From their experience, many clients have made the mistake of involving these specialists at a relatively late point in the process.

*The rest of the discussion remained broad but still managed to navigate several distinct topics:*

One conversation revolved around efficient decision-making processes. The main question was, “**What does an efficient decision-making process look like?**”. Like the other prompts, the attendees had a chance to provide some quick initial responses. Some key responses included: “Understanding ROI and feasibility, in parallel”, “Transparency”, “Scalability”, “Decision support tools”, “The need to address a business issue or problem”, and the ability to “Complement other standard digital solutions”. In addition to these short comments, one of the attendees was willing to provide an in-depth insight into their company’s experience: “There’s always going to be more ideas, [compared to the] resources that we can apply. It’s important to communicate the potential/payback of any initiative. It takes good storytelling and communication to have these initiatives promoted by executives. Motivation comes from the affected teams, and this is balanced with the company’s resources and capabilities”.

In a related discussion, the attendees tried to identify the enabler(s) of digital transformation at their companies. Several attendees claimed that direction is initiated and driven at the C-level, but some claimed otherwise. Other enablers included plant managers (who are directly responsible for selling new technologies to floor workers), end-users, and plants with successful deployments. The consensus was that many different enablers exist within each company, playing different roles at different stages of their shared initiatives.

Another key discussion revolved around the relationship between Information Technology (IT) and Operational Technology (OT). In general, attendees seemed to agree that IT and OT are converging; this is due to increasing demand for computer science skills throughout the entire industry. As companies

begin to expand their IT forces, it has become increasingly important for other divisions to understand their work, and vice-versa. Among attendees, it became clear that there are different ways to implement this convergence within a company. Some claimed that it is better to keep IT and OT as distinct units and provide each with the training to understand how the other unit functions properly. Other companies think it is better to have personnel from each unit directly involved in the other unit's operations.

An example of this would be an IT employee who is comfortable with "getting grease under their fingernails". These approaches are different, but they both represent convergence at an enterprise level. Additionally, it's also vital to have executive-level guidance to determine the right direction for a respective company, based on needs and capabilities.

## Appendix C: Follow-up Survey

### Technology

1. "For Industry 4.0 initiatives, has your company defined a formalized Cloud adoption strategy? If so, how would you describe it?"
2. "To what extent will factory data and analytics workloads be sent to the Cloud?"
3. "Do your manufacturing facilities have concerns about Cloud deployment? If so, what are your primary concerns?"
4. "Industry 4.0 adoption is underpinned by several core technologies. To what extent has your organization adopted the following technologies?":
  - 5G Networking
  - Remote Performance Monitoring
  - Data Lakes
  - Self-Service BI (Analytical Dashboards and Reports)
  - Machine Learning
  - Edge Computing
  - Computer Vision
  - Automation (Robots)
  - Augmented Reality (A/R)
  - Digital Twin (Simulation)
5. "Data, analytics and machine learning are critical components of Industry 4.0 digital transformation. To what extent does your organization experience challenges in the following areas?":
  - Retrofitting legacy Systems with Sensors
  - Data Connectivity to Operational Technology Protocols
  - Data Ingestion (to Data Center or Cloud)
  - Data Consolidation for Analytics
  - Data Quality/Data Cleansing
  - Lack of Data Standards
  - Self Service Business Intelligence (Dashboards and Reports)
  - Machine Learning
  - Streaming Analytics

## Processes

1. “Critical to Industry 4.0 is the fact that factories have become connected, providing new opportunities to leverage data (i.e. from sensors, enterprise operational systems and image/video/audio sources), advanced analytics and machine learning to digitally transform manufacturing operations. Consequently, a wide range of manufacturing processes have been impacted. Please indicate the extent to which your company has considered the following use cases”:
  - Digital Twin/Process Simulation
  - Equipment and process automation
  - Remote Performance Monitoring
  - Computer Vision Quality Inspection
  - Manufacturing Quality Process Optimization
  - Demand-Driven Manufacturing
  - Supply Chain Optimization
  - Equipment Predictive Maintenance
  - 3D Printing/Additive Manufacturing
  - Factory Energy Management
  - Computer Vision Worker Safety
  - Augmented Reality